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INSTRUCTION MANUAL

MODEL 413A

MICRO-MICROAMMETER



KEITHLEY INSTRUMENTS



INSTRUCTION MANUAL

MODEL 413A

MICRO-MICROAMMETER

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*If a change in the instrument affects the instructions, the correction is printed on a yellow sheet at the back of the manual.

SECTION I - INTRODUCTION

The Keithley Model 413A micro-microammeter is a line operated vacuum tube electrometer with a logarithmic meter scale which covers the range 10^{-4} to 10^{-12} ampere without range switching.

The features include full-scale voltage drop at the input of less than five millivolts, zero drift of less than 1/6 decade in 24 hours, good accuracy, built-in calibration standards and large output voltage. The output is sufficient to drive the numerous potentiometer-rebalance 50 millivolt recorders. One output terminal is at ground, making it convenient to connect cathode ray oscilloscopes or pen-driving amplifiers, similar to Brush and Sanborn equipment.

The major panel controls are the OPERATE-CALIBRATE switch and the SET 10^{-10} control which establishes a reference point on the logarithmic scale. Minor controls are the RECOVER button, AMPLIFIER BAL adjustment, SET 10^{-6} adjustment, and the ON-OFF switch.

SECTION II - DESCRIPTION

The current range covered is 10^{-4} to 10^{-12} ampere and is displayed on a six inch panel meter for maximum readability. Accuracy is within plus or minus 0.2 decade and the output voltage is six millivolts per decade plus or minus 20%. Positive currents can be accepted and the output voltage is in the negative direction.

Standardization of the 413A is accomplished by turning the OPERATE-CALIBRATE switch to the 10^{-10} position and setting the meter at 10^{-10} by means of the SET 10^{-10} control knob. The calibration signal is supplied by means of a mercury battery and a 10^{10} ohm, 2% resistor.

Calibration of the 413A may be checked by advancing the OPERATE-CALIBRATE switch to 10^{-6} ampere after standardization has been accomplished as above. Adjustment may be made if necessary by means of a front panel screw-driver control labeled SET 10^{-6} AMP.

Amplifier balance may be finally checked by then advancing the OPERATE-CALIBRATE switch to AMPLIFIER BAL and checking to see if the meter needle goes to 10^{-12} . If necessary, a front panel control labeled AMPLIFIER BAL may be used to adjust this setting.

In general only the SET 10^{-10} control is routinely used. The other adjustments will require infrequent adjustment.

Input impedance is minimized by negative feedback. The voltage drop across the input terminals will be less than five millivolts for any position across the meter scale provided that the amplifier balance is properly set.

Grid current is less than 5×10^{-14} ampere and will not affect operation of the instrument.

Input switch labeled RECOVER is located at left side of the panel. Its purpose is to short out the feedback diode and allow quick dissipation of spurious charges which sometimes accumulate on the input of a micro-microammeter, or are caused by overloading the input.

Drift. After one hour warm up, the instrument will not drift more than $1/6$ of a decade over a 24 hour period.

Output is provided for driving recorders. The amplifier will develop 50 millivolts for full-scale meter deflection. Connection can be made to the OUTPUT connector at the rear of the chassis.

Response Speed of the 413A depends upon the current and also upon the capacitance of the external circuitry. Because of the method of application of the negative feedback, the slowing effects of capacitance from the high input terminal to ground have been greatly reduced, but are still significant. Table I below gives typical response speeds; viz; the time of 90% response to a step function.

TABLE I

RISE TIME - to 90% of final current
with no significant external capacitance

<u>Current Range</u>	<u>Rise Time in Milliseconds</u>
10 ⁻¹¹	30
10 ⁻¹⁰	10
10 ⁻⁹	10
10 ⁻⁸ -10 ⁻⁴	10

If averaging of statistical fluctuations at low current is desired, a polystyrene capacitor may be placed across the feedback diode. The exact value will depend upon the response desired for the particular application but usually will be in the range of 5 to 50 micro-microfarads.

Amplifier Noise is principally power frequency, and is .2 millivolts rms max at the output terminals, irrespective of the current range. From the most general point of view, grid current and amplifier zero drift are also background noise; these have already been discussed.

Circuit Description. A logarithmic scale is obtained by negative feedback from output to input with a diode whose emission is limited by negative plate cathode voltages. The diode used is an Amperex EA-52 diode.

The feedback from the output is connected at R107 so that variation of R107 will control the potential in series with the output. This potential is necessary to buck out the voltage across the diode in order that the output can be kept at ground potential when the input is at ground potential.

The calibration circuit consists of a mercury battery, BA 8 (RM401R), and resistors R101, R102, R103 and R104. The OPERATE-CALIBRATE switch is used to select the desired signal, either 10⁻¹⁰ or 10⁻⁶ ampere. In the AMPLIFIER BAL position the diode is shorted out. In this condition the logarithmic characteristic of the amplifier is removed and the circuit is simply a linear feedback amplifier whose zero corresponds to the 10⁻¹² position on the meter. The amplifier BAL screw-driver potentiometer adjusts the amplifier zero. With proper balance of the amplifier, there will be negligible dc voltage at the input of the Model 413A in normal operation.

Calibration. The meter calibration is established by alternating between the 10^{-10} and 10^{-6} positions of the OPERATE-CALIBRATE switch, which causes 10^{-10} and 10^{-6} ampere to flow in the input of the Model 413A. The corresponding potentiometers are adjusted until these calibration signals read properly on the meter. The 10^{-10} SET controls the gain of the amplifier and thus adjusts the change of the diode voltage with current, so that the rest of the scale reads correctly. Once these adjustments are made only the SET 10^{-10} control needs to be used to compensate for drift. The other controls will require infrequent adjustment.

The RECOVER switch shorts out the diode and allows the circuit to recover from large overloads quickly.

All plate and filament supplies are regulated by a Sola resonant transformer. Conventional half-wave rectifier filter circuits supply the B+ and B- potentials.

SECTION III - OPERATION

Connect the input to the current source and the output to the recorder or external indicator if desired.

Plug the power cord into a 115 volt 60 cps outlet. Note that since a Sola resonant regulating transformer is used, the power frequency as well as the voltage must be of the proper value.

Turn OPERATE-CALIBRATE switch to 10^{-10} ampere.

Turn on power switch.

After about 15 minutes warm-up set meter to 10^{-10} with SET 10^{-10} control.

Check calibration by advancing OPERATE-CALIBRATE switch to 10^{-6} position. Adjust if necessary as discussed in Section II.

Check amplifier balance by advancing OPERATE-CALIBRATE switch to AMPLIFIER BAL. Adjust if necessary.

Recheck at 10^{-10} and readjust if necessary. Instrument is now ready to operate. Recheck occasionally for drift by using 10^{-10} position on OPERATE-CALIBRATE switch and by adjusting with SET 10^{-10} control. The screw driver adjustments should require infrequent attention.

Input, using cabling.

The current source should be connected to the input connector with the high impedance side of the current source associated with central conductor of the connector. The lead-in cable should be polyethylene, polystyrene, or teflon insulated coaxial cable, and the connector should have teflon insulation. During preparation of cable and connectors, it is essential that all high impedance surfaces be kept scrupulously clean to avoid leakage. With graphite coated cable, it is necessary to avoid tracking graphite onto the high impedance surfaces of the cut end of the insulation and the teflon surface of the connector. Movement of the cable during measurement should be avoided since this will cause spurious needle movements, because of capacitance changes and generation of static charges.

RECORDING: The Model 413A is provided with an output connector on the rear of the chassis for recording. The output for full-scale meter deflection is minus 50 millivolts. Amphenol 80PC2F is the chassis connector, Amphenol 80MC2M is the mating plug. Terminal #1 is ground.

The Speed of Response, or the time constant of an input transducer and micro-microammeter, depends upon the speed of response of the circuitry of the instrument and also upon the capacitance of the current source and its connecting cable. Because of the way the negative feedback is applied in the Model 413A, the external input capacitance is not nearly as important as in the older systems using a voltmeter across a shunting resistor or diode, and quite large capacitances can be tolerated without having an impossibly slow response. Thus, a cable run from an ion chamber to the micro-microammeter is permissible.

+216 Volts. A connector has been mounted on the back face of the chassis to provide +216 volts for polarizing an ion chamber. The potential is derived from OB2 regulators and is well filtered. The supply can be short circuited without damaging it. The chassis connector is Amphenol 80-C and 80-M is the mating plug.

SECTION IV - MAINTENANCE

The Keithley Model 413A Micro-microammeter has been designed to give long, trouble-free service. High quality components have been used throughout, and the circuits are stabilized by a substantial amount of negative feedback.

DR14150-C at the back is the detailed circuit schematic diagram of the Model 413A. The circuit operation was discussed in Section II. Description.

Vacuum tubes V1 and V2 are two electrometer tubes and are located in an aluminum can which plugs onto the top of the chassis near the input terminals. These tubes have been selected, matched and labeled; V1 and V2 are Keithley part EV5886-8. It is recommended that the complete input tube assembly, Model 4102, be kept on hand for replacement purposes.

Feedback diode VC is an Amperex EA-52 diode which is tested for its logarithmic characteristic.

INSULATION: All insulation for the high impedance conductors is made of teflon, as are the contact insulators on the function switch. This should give satisfactory service in all humidities. Occasionally, the high impedance insulators should be inspected to insure that they are free from dirt and dust, and brushed off if necessary.

CONNECTOR CAP: The cap for the input connector should be kept in place whenever the connector is not being used. In storage and in transport, it keeps the insulation from accumulating dust, dirt and moisture. Before screwing the cap back onto the connector, be certain that it is clean, so the insulation will not be contaminated and so that a low impedance bridging conductor will not be formed between the high impedance contact and the grounded cap.

Reference Voltage Battery BA-8 should be replaced once yearly.

Before storing the Model 413A for any long period of time, remove the battery. Use a new battery when the instruments is again put into operation.

REPLACEABLE PARTS LIST - MODEL 413A

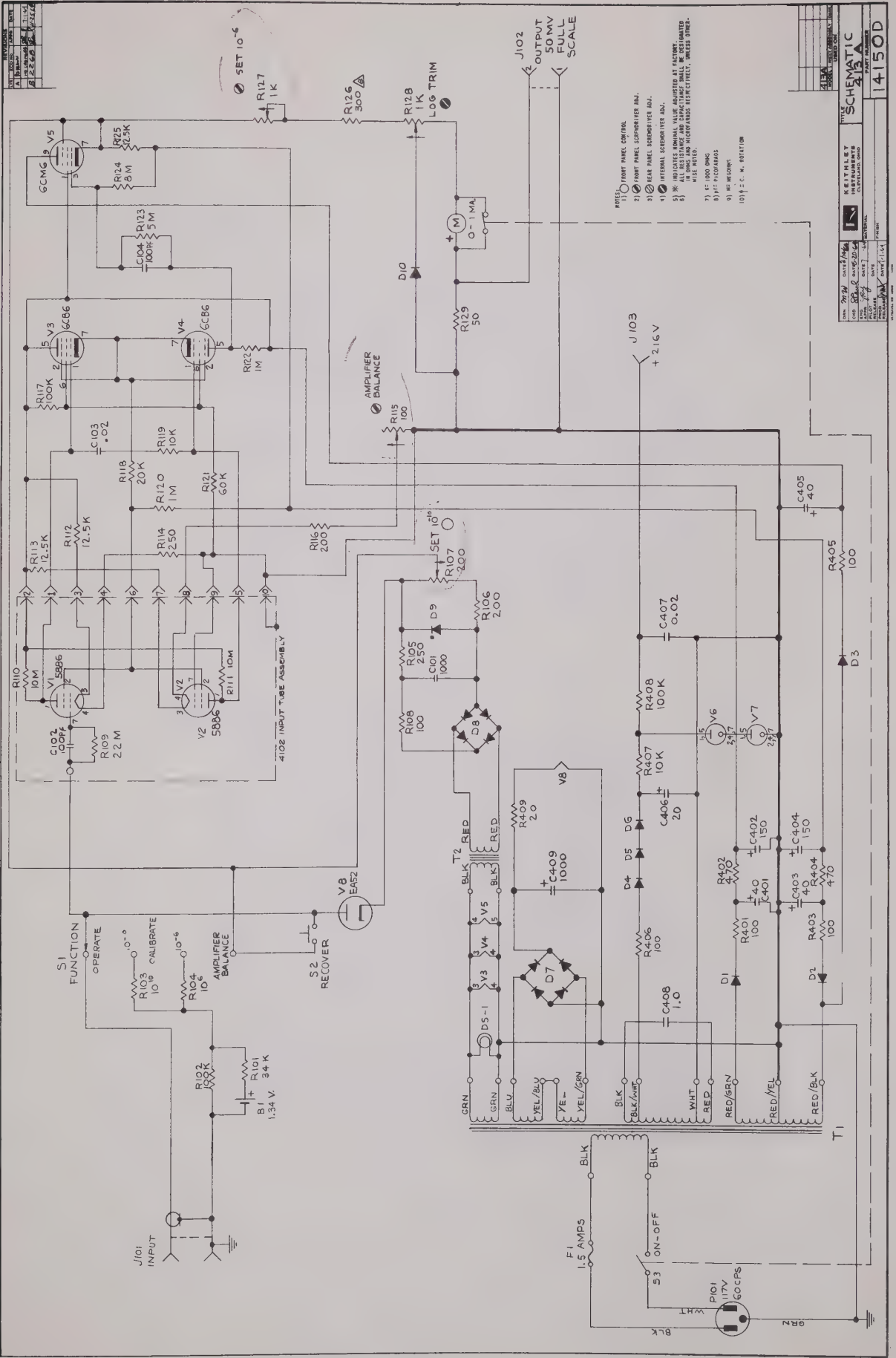
Circuit Desig.	Description	Part No.
BA-1	Battery, 1.35 Volt (Mallory RM 401R)	BA-8
C-101	1000 mfd. 12 Volt, Electrolytic, Capacitor	C11-1000
C-102	100 mmf, 600 Volt, Disc., Capacitor	C22-100
C-103	.02 mfd. 600 Volt, Disc., Capacitor	C22-.02
C-104	100 mmf, 600 Volt, Disc., Capacitor	C22-100
C-401	40 mfd. 250 Volt, Electrolytic, Capacitor	C27-40
C-402	150 mfd. 150 Volt, Electrolytic, Capacitor	C9-150
C-403	40 mfd. 250 Volt, Electrolytic, Capacitor	C27-40
C-404	150 mfd. 150 Volt, Electrolytic, Capacitor	C9-150
C-405	40 mfd. 250 Volt, Electrolytic, Capacitor	C27-40
C-406	20 mfd. 450 Volt, Electrolytic, Capacitor	C8-20L
C-407	.02 mfd. 600 Volt, Disc., Capacitor	C22-.02
C-408	1.0 mfd. Capacitor	Supplied with TR-17
C-409	1000 mfd. 2 Volt, Electrolytic Capacitor	C11-1000
C-410	5 mmf, Polystyrene Capacitor	C31-5
FU-1	Fuse - $1\frac{1}{2}$ ampere	FU-8
ME-1	Meter, 1 ma	ME-37
R-101	34K Deposited Carbon, 1/2 w. 1% Resistor	R12-34K
R-102	100K Deposited Carbon, 1/2 w. 1% Resistor	R12-100K
R-103	10^{10} Hi-meg, Resistor	R20- 10^{10}
R-104	10^6 Deposited Carbon, 1/2 w. 1%, Resistor	R12-1M
R-105	250 Deposited Carbon, 1/2 w. 1%, Resistor	R12-100
R-106	200 Deposited Carbon, 1/2 w. 1%, Resistor	R12-50
R-107	200 10 - turn, Potentiometer	RP4-200

REPLACEABLE PARTS LIST - MODEL 413A

Circuit Desig.	Description	Part No.
R-109	22M Composition 1/2 w. 10%, Resistor	R1-22M
& R-110 R-111	10M Deposited Carbon 1 w. 1%, Resistor	R13-10M
& R-112 R-113	12.5K Wire Wound, 7 w. 3%, Resistor	R7-12.5K
R-114	250 Wire Wound, 1/4 w. 1%, Resistor	R18-15-250
R-115	100 Linear 2 w. 10%, Potentiometer	RP3-100
R-116	200 Wire Wound 1/4 w., 1%, Resistor	R18-15-200
R-117	100K Deposited Carbon, 1/2 w. 1% Resistor	R12-100K
R-118	20K Deposited Carbon 1/2 w. 1%, Resistor	R12-20K
R-119	10K Wire Wound 5 w. 3%, Resistor	R4-10K
R-120	10 ⁶ Deposited Carbon, 1/2 w. 1%, Resistor	R12-1M
R-121	60K Deposited Carbon 1/2 w. 1%, Resistor	R12-60K
R-122	10 ⁶ Deposited Carbon, 1/2 w. 1%, Resistor	R12-1M
R-123	5M Deposited Carbon, 1/2 w 1%, Resistor	R12-5M
R-124	8M Deposited Carbon 1 w. 1%, Resistor	R13-8M
R-125	12.5K Wire Wound, 7 w. 3%, Resistor	R7-12.5K
R-126	Resistor, Deposited Carbon 1/2 w. 1%, 333	R12-333
R-127	Wire Wound 2 w. 10%, Potentiometer 1 K	RP3-1K
R-128	1K Composition 1 w. 10%, Potentiometer	RP13-1000
R-129	Resistor, Deposited Carbon 1/2 w., 1%, 50	R12-50
R-401	Resistor, Composition 1/2 w, 10%, 100	R1-100
R-402	470 Composition 1/2 w. 10%, Resistor	R1-470
R-403	Resistor, Composition 1/2 w., 10%, 100	R1-100
R-404	470 Composition 1/2 w. 10%, Resistor	R1-470
& R-405 R-406	Resistor, Composition 1/2 w. 10%, 100	R1-100

REPLACEABLE PARTS LIST - MODEL 413A

Circuit Desig.	Description	Part No.
R-407	10K Composition 1/2 w. 10%, Resistor	R1-10K
R-408	100K Composition 1/2 w. 10%, Resistor	R1-100K
R-409	Resistor 20 ohm 5 watts	R54-20
RF-1	Rectifier, Diode 52 Volt, 5 ma, 2V1	RF-11
RF-2	Zener Diode 1N469	DZ-1
thru SR-1 SR-6	Rectifier, Selenium 65 ma, 130 Volt	RF-18
SR-7	Rectifier, Selenium 30 ma.	RF-6
SR-8	Rectifier, Selenium .6A	RF-7
SW-1	Switch, Function	SW-37-1
SW-2	Switch, Recover - Push Button	
SW-3	Switch, Toggle - D.P.D.T.	SW-14
T-1	Transformer, Sola 71354	Regulating TR-17
T-2	Transformer, Filament	TR-11
V-1	Tube, 5886	EV 5886-8
V-2	Tube, 5886	EV 5886-8
& V-3 V-4	Tube, 6 CB 6	EV 6CB6
V-5	Tube, 6 CM 6	EV 6CM6
& V-6 V-7	Tube, Voltage Regulating - OB-2	EV OB 2
V-8	Tube, 6923/EA.52 Amperex	EA-52



WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof (except tubes and batteries) which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the plant directly, DDD 216-795-2666. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has authorized field repair facilities in Los Angeles and Albuquerque.

To insure prompt repair or recalibration service, please contact your local field representative, or the plant directly, before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

CHANGE NOTICE

December 4, 1964

MODEL 413A MICRO-MICROAMMETER

Page 4-3. Change to the following:

R-126 Resistor, Deposited Carbon, 1/2 watt, 1%, 300 Ω , Part No. R12-300



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